SWASH-PLATE COMPRESSOR HAVING A PISTON IN WHICH A CONTACT SURFACE TO BE CONTACTED WITH A SHOE IS CONTINUOUSLY AND EXTENSIVELY FORMED

This application claims priority to prior Japanese application JP 2002-360766, the disclosure of which is incorporated herein by reference.

Background of the Invention:

This invention relates to a swash-plate compressor for use in, for example, a refrigerating circuit of an automotive air conditioner.

A swash-plate compressor of the type comprises a compressor body or a cylinder block having a plurality of cylinder bores spaced from one another in a circumferential direction, a plurality of pistons reciprocally movable in the cylinder bores, respectively, a swash plate slidably engaged with one ends of the pistons, and a drive shaft for rotating the swash plate. The drive shaft has one end to which a pulley is attached. By transmitting an external drive force to the pulley, the drive shaft is rotated.

Each piston has one end provided with a pair of engaging portions faced to each other with the swash plate interposed therebetween, and a side wall portion connecting the engaging portions to each other. Between the engaging portions and the swash plate, a pair of semispherical shoes which serve as sliding members slidably contacted with the swash plate are interposed, respectively. Each of the engaging portions is provided with a contact surface to be slidably contacted with a spherical surface portion of the shoe. The side wall portion of the piston is provided with a recessed portion receiving a peripheral portion of the shoe in a non-contact manner.

In an automotive air conditioner, a carbon dioxide refrigerant is increasingly used in a refrigerating circuit instead of a chlorofluorocarbon refrigerant in view of environment protection. A compressor adapted to be used with the carbon dioxide refrigerant is disclosed, for example, in Japanese Patent Application Publication No. 2002-31047 (JP-A).

As compared with the case where the chlorofluorocarbon refrigerant is used, the discharge volume of the compressor is reduced down to 1/6 to 1/8 when the carbon dioxide refrigerant is used. Therefore, the piston having a small outer diameter is used. On the other hand, the working pressure is increased to about 10 times and the load imposed upon the swash plate by the piston is increased by about 20-30%. Therefore, the shoe having a large outer diameter must be used so as to accommodate such a large load from the piston.

However, use of the shoe large in outer diameter generally requires the side wall portion of the piston to be enlarged outward, resulting in an increase in size of the compressor. Alternatively, the above-mentioned recessed portion may be reduced in thickness and increased in depth without enlarging the side wall portion. In this event, however, the strength of the piston is decreased.

When the tilting angle of the swash plate is increased with the piston reaching a top dead center or a bottom dead center, the displacement of each shoe is also increased in a radial direction of the piston in the manner known in the art. Sometimes, a part of the spherical portion of each shoe may move out of the contact surface of the engaging portion. In this event, the contact area between the spherical portion of the shoe and the contact surface of the engaging portion is reduced. Such reduction in contact area results in an abnormal sliding condition of the shoe. For example, smooth sliding movement between the shoe and the engaging portion is interfered or inhibited. Sometimes, the shoe may be released and dropped from its position between the swash plate and the engaging portion.

Summary of the Invention:

It is therefore an object of the present invention to provide a swash-plate compressor which is capable of increasing an outer diameter of a sliding member without causing an increase in size of the compressor and a decrease in strength of a piston and which is capable of reliably preventing the sliding member from sliding in an abnormal sliding condition or from being released.

Other objects of the present invention will become clear as the description proceeds.

According to an aspect of the present invention, there is provided a swash-plate compressor for compressing a fluid. The compressor comprises a cylinder block having a cylinder bore, a piston having a first end portion reciprocally movable in the cylinder bore and a second end portion opposite to the first end portion, the second end portion having a pair of engaging portions faced to each other with a space left therebetween and a side wall portion connecting the engaging portions to each other, a swash plate having a part inserted between the engaging portions and driven to rotate, and a pair of sliding members interposed between the engaging portions and the swash plate, respectively. Each of the sliding members having a flat portion slidably contacted with the swash plate and a spherical portion opposite to the flat portion. Each of the engaging portions having a contact surface slidably contacted with the spherical portion. Each of the contact surfaces extending to the side wall portion.

Brief Description of the Drawing:

Fig. 1 is a vertical sectional view of a swash-plate compressor according to one embodiment of the present invention;

Fig. 2 is a front view of a piston used in the swash-plate compressor illustrated in Fig. 1;

Fig. 3 is a side view of the piston illustrated in Fig. 2;

Fig. 4 is a sectional view showing the relationship between the piston and shoes;

Fig. 5 is a sectional view for describing the force acting between the piston and the shoes illustrated in Fig. 4;

Fig. 6 is a sectional view of a piston as a comparative example;

Fig. 7 is a sectional view for describing the force acting between the piston and shoes illustrated in Fig. 6;

Fig. 8 is a front view of a modification of the piston according to this invention; and

Fig. 9 is a front view of another modification of the piston according to this invention.

Description of the Preferred Embodiments:

Referring to Figs. 1 through 4, description will be made of a swash-plate compressor according to an embodiment of the present invention.

The swash-plate compressor illustrated in Fig. 1 is used, for example, in a refrigerating circuit of an automotive air conditioner and is adapted to compress a carbon dioxide refrigerant. The swash-plate compressor is of a so-called single-head piston type and includes a compressor body 1 having a cylinder block. The compressor body 1 has one end provided with a plurality of cylinder bores 2 spaced from one another in a circumferential direction. Each of the cylinder bores 2 receives one end of a piston 10 inserted therein to be reciprocally movable. The piston 10 has a small outer diameter and intended to be used with the carbon dioxide refrigerant.

As well known, a cylinder head 4 is attached to one end face of the compressor body 1 through a valve assembly 3. The cylinder head 4 has a discharge chamber 4a formed at its center and a suction chamber 4b formed around the discharge chamber 4a. Each of the discharge chamber 4a and the suction chamber 4b is communicable with the cylinder bores 2 through valves

contained in the valve assembly 3. Furthermore, the discharge chamber 4a and the suction 4b are connected to opposite ends of the refrigerating circuit (not shown), respectively.

The swash-plate compressor illustrated in the figure further comprises a rotatable drive shaft 5. The drive shaft 5 has one end to which a pulley 6 is mounted. In order to engage and disengage the pulley 6 and the drive shaft 5, an electromagnetic clutch 8 is provided. By supplying the pulley 6 with an external drive force and exciting the electromagnetic clutch 8, the drive shaft 5 is rotated.

In a crank chamber 1a formed inside the compressor body 1, a swash plate 11 is connected through a hinge 7a to a rotor 7 rotating integrally with the drive shaft 5. As a consequence, the swash plate 11 is tiltable with respect to the drive shaft 5 and rotatable together with the drive shaft 5. The swash plate 11 is urged towards each piston 10 by a coil spring 7b wound around the drive shaft 5.

The piston 10 has the other end with which a peripheral portion of the swash plate 11 is slidably engaged in a structure which will presently be described. Each piston 10 has one end provided with a pair of engaging portions 10a and 10b faced to each other with the swash plate 11 interposed therebetween, and a side wall portion 10c extending from one side end of one engaging portion 10a to one side end of the other engaging portion 10b. The engaging portions 10a and 10b and the side wall portion 10c are integrally formed. Between the engaging portions 10a and 10b and the swash plate 11, a pair of shoes 12 are interposed, respectively. The shoes 12 serve as sliding members slidably contacted with the swash plate 11. Each of the shoes 12 has a spherical portion 12a and a flat portion 12b opposite to the spherical portion 12a and slidably contacted with the swash plate 11.

The piston 10 has a contact surface 14 extending over the engaging portions 10a and 10b and the side wall portion 10c to be slidably contacted with the spherical portions 12a of the shoes 12. In other words, the contact surface 14 is continuously formed from the one engaging portion 10a through the side wall portion 10c to the other engaging portion 10b. It may be understood that the contact surface 14 is extensively formed on each of the engaging portions 10a and 10b and the side wall portion 10c and that these contact surfaces 14 are connected to one another. The contact surface 14 is formed along a spherical surface having a curvature equal to that of the spherical portion 12a of each shoe 12. The swash plate 11 is adapted to accommodate a large load owing to the use of the carbon dioxide refrigerant. For example, the swash plate 11 has a sufficiently large thickness.

When the drive shaft 5 is rotated by the drive force supplied to the pulley 6, the swash plate 11 is rotated together with the drive shaft 5. Owing to the inclination of the swash plate 11, each piston 10 reciprocally moves in an axial direction. When the piston 10 reciprocally moves, the carbon dioxide refrigerant circulates through a refrigerating circuit. Specifically, the carbon dioxide refrigerant is sucked from the refrigerating circuit through the suction chamber 4b into the cylinder bores 2 and is discharged through the discharge chamber 4a to the refrigerating circuit. Due to a pressure difference between the suction chamber 4b and the crank chamber 1a, each piston 10 is applied with a pressure on its rear side (on the side of the crank chamber 1a). Depending upon the above-mentioned pressure, the tilting angle of the swash plate 11 is changed so that the discharge volume by the piston 10 is varied. The cylinder head 4 is provided with a pressure adjusting mechanism 15 for adjusting the pressure difference between the suction chamber 4b and the crank chamber 1a.

When the piston 10 is driven, the swash plate 11 slides along the flat portion 12b of each shoe 12 in contact therewith. Simultaneously, each shoe 12 slides along the contact surface 14 with the spherical portion 12a kept in contact with the contact surface 14. If the tilting angle of the swash plate 11 is increased, for example, when the piston 10 reaches a top dead center or a bottom dead center, the displacement of each shoe 12 is increased. However, since the contact surface 14 is continuously formed over the engaging portions 10a and 10b and the side wall portion 10c, the spherical portion 12a slides along the contact surface 14 continuously in contact therewith even if the shoe 12 is displaced towards the side wall portion 10c as illustrated in Fig. 4. Therefore, even if a shoe 12' greater in outer diameter is used as depicted by a dash-and-dot line in the figure, an increase in diameter of the shoe 12' results in an increase in contact area between the spherical portion 12a and the contact surface 14 and does not require any modification in shape and size of the contact surface 14.

Referring to Fig. 5, when the shoe 12 is displaced towards the side wall portion 10c, the contact area between the spherical portion 12a of the shoe 12 and the contact surface 14 is not reduced. Therefore, as depicted by arrows in the figure, reactive force applied from the contact surface 14 upon the shoe 12 is uniformly distributed throughout a whole of the spherical portion 12a.

Next referring to Fig. 6, a piston 13 in a comparative example has engaging portions 13a and 13b and a side wall portion 13c between the engaging portions 13a and 13b. Each of the engaging portions 13a and 13b is provided with a contact surface 13d. On the other hand, the side wall portion 13c is provided with a recessed portion 13e receiving a lateral side of the shoe 12 in a non-contact manner. In case where the shoe 12' having a greater diameter is used as depicted by a dash-and-dot line in the figure, the recessed portion 13e will interfere with the lateral side of the shoe 12' unless the depth of

the recessed portion 13e is increased. In order to avoid such interference, the depth of the recessed portion 13e must be increased. For this purpose, the side wall portion 13c is enlarged outward in a lateral direction of the piston 13. Disadvantageously, this results in an increase in size of the compressor body 1. Alternatively, the depth of the recessed portion 13e can be increased by reducing the thickness of the side wall portion 13c without enlarging the side wall portion 13c outward in the lateral direction of the piston 13. In this event, however, the strength of the piston 13 is decreased.

Referring to Fig. 7, consideration will be made about the force acting between the shoe 12 and the contact surface 13d in case where the side wall portion 13c is provided with the recessed portion 13e receiving the lateral side of the shoe 12. In this case, a part of the spherical portion 12a of the shoe 12 displaced towards the side wall portion 13c moves out of the contact surface 13d of each of the engaging portions 13a and 13b. Therefore, the contact area between the spherical portion 12a of the shoe 12 and the contact surface 13d is reduced. As a consequence, reactive force applied from the contact surface 13d upon the shoe 12 is concentrated to a part of the spherical portion 12a as depicted by arrows in the figure. This may result in an abnormal sliding condition of the shoe 12 or a release of the shoe 12 from the piston 13.

As compared with the comparative example mentioned above, the swash-plate compressor illustrated in Fig. 1 has a structure in which the contact surface 14 is continuously formed over the engaging portions 10a and 10b and the side wall portion 10c. With this structure, even if the shoe 12 is displaced towards the side wall portion 10c, the spherical portion 12a of the shoe 12 is continuously kept in contact with the contact surface 14. Therefore, even if the shoe 12' having a greater outer diameter is used, it is unnecessary to modify the shape or the size of the contact surface 14. In addition, it is unnecessary to enlarge the side wall portion 10c outward in the lateral direction of the piston

10 and to reduce the thickness of the side wall portion 10c. Thus, it is possible to avoid an increase in size of the compressor body 1 and a decrease in strength of the piston 10.

Even if the shoe 12 is displaced towards the side wall portion 10c, the reactive force from the contact surface 14 can uniformly be received by a whole of the spherical portion 12a. Therefore, even if the tilting angle of the swash plate 11 is large, the shoe 12 can continuously smoothly slide along the contact surface 14. Accordingly, it is possible to reliably prevent an abnormal sliding condition and a release of the shoe 12 from the piston 10 and to distribute the reactive force from the contact surface 14 so that occurrence of local wear is avoided. Thus, the above-mentioned structure of this invention is advantageous also in view of improvement of the durability.

Furthermore, the contact surface 14 is continuously formed over the engaging portions 10a and 10b and the side wall portion 10c. Therefore, it is possible to accommodate not only an increase in diameter of each shoe 12 but also an increase in sliding range of each shoe 12. Thus, the versatility can be improved. In this case, since the contact surface 14 is formed on the side wall portion 10c by cutting, the piston 10 can be reduced in weight. This structure is advantageous if it is desired to reduce the inertial force. Because the contact surface 14 is continuously formed between the engaging portions 10a and 10b, a lubricating oil 15 can be retained on the contact surface 14 between the shoes 12 as illustrated in Fig. 5. Thus, it is possible to reliably supply the lubricating oil 15 to each shoe 12. As a consequence, each shoe 12 can very effectively be prevented from seizure.

Furthermore, it is possible to easily produce the contact surface 14 continuously formed. In this case, the contact surface 14 is formed along a spherical surface having a curvature equal to that of the spherical portion 12a of each shoe 12. Therefore, the contact surface 14 can be easily formed by

cutting or the like so that the productivity is improved.

Furthermore, the durability can be improved without causing an increase in size of the compressor body 1 and a decrease in strength of the piston 10 as described above. Therefore, it is possible to use the carbon dioxide refrigerant high in working pressure. Thus, by the use of the carbon dioxide refrigerant, it is possible to achieve the refrigerating circuit advantageous in environment protection. Particularly when the compressor is used in the automotive air conditioner, the structure of this invention is very effective.

As illustrated in Fig. 8, the contact surface 14 may be formed continuously from each of the engaging portions 10a and 10b to a part of the side wall portion 10c.

As illustrated in Fig. 9, the contact surface 14 may be divided by a groove 10e.

By forming an integral member corresponding to a combination of the swash plate 11 and the rotor 7, it is possible to provide a fixed-volume or fixed-displacement compressor comprising a swash plate having a predetermined fixed tilting angle with respect to the drive shaft 5. In such a compressor, this invention can similarly be embodied to achieve the similar effect.

Although the present invention has been shown and described in conjunction with a few preferred embodiments thereof, it should be understood by those skilled in the art that the present invention is not limited to the foregoing description but may be changed and modified in various other manners without departing from the spirit and scope of the present invention as set forth in the appended claims. For example, the present invention is not limited to a compressor of a single-head piston type but is applicable to a swash-plate compressor using a double-head piston.